

STUDY OF ATMOSPHERIC FLOWS in A complex site in India Using ZEPHYTOOLS® CFD MODELING

2nd Symposium on Openfoam in Wind Energy

National Renewable Energy Laboratory

Renewable Energy and Sustainable Energy Institute

University of Colorado, Boulder (USA), May 19 and 21, 2014

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ReNew Power

- ReNew is one of the leading Independent Power Producer (IPP) in India having installed wind capacity of 457MW. By 2015 the company aims to reach a 1 gigawatt capacity in renewables.
- ReNew has secured equity investment from Goldman Sachs, a leading global investment bank and an active investor in clean technology

MeteoPole

- Boutique Consulting Firm Specialized in Bankable Services and Power Performance Optimization Services. Headquartered in Paris with operating offices across 5 countries.
- MeteoPole has international experience of handling more than 17 GW of projects all across the world

Objectives

- To evaluate the relative performance of wind speed estimation techniques commonly employed in the wind industry, and the advantages CFD modelling techniques could have over the linear modelling, when used for complex terrain sites
- To help in ZephyTOOLS® open-source project by setting a new fully reproducible validation case that can be used and studied by each user

Methodology

- Predicting wind speeds from initiation point to target points (mast locations) using WAsP & ZephyTOOLS OpenFOAM®-based CFD model
- Validate the flow simulated cross prediction results with actual measurements
- Post-process the project in ZephyTOOLS and package it as a new validation case to be shared and reproduced by any

Site & Measurements

Project status

Modelling Parameters

Case Study Results

Conclusion

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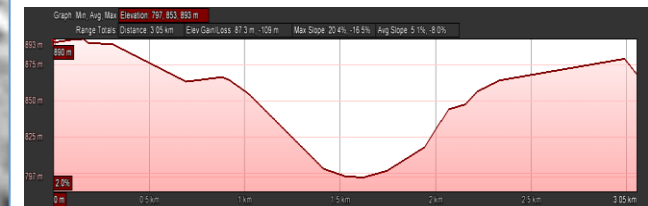
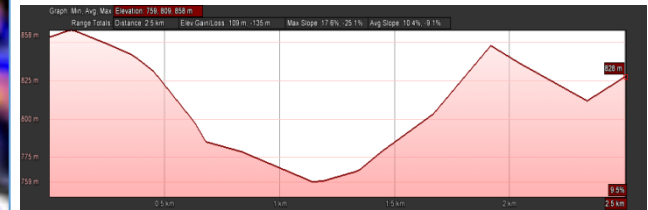
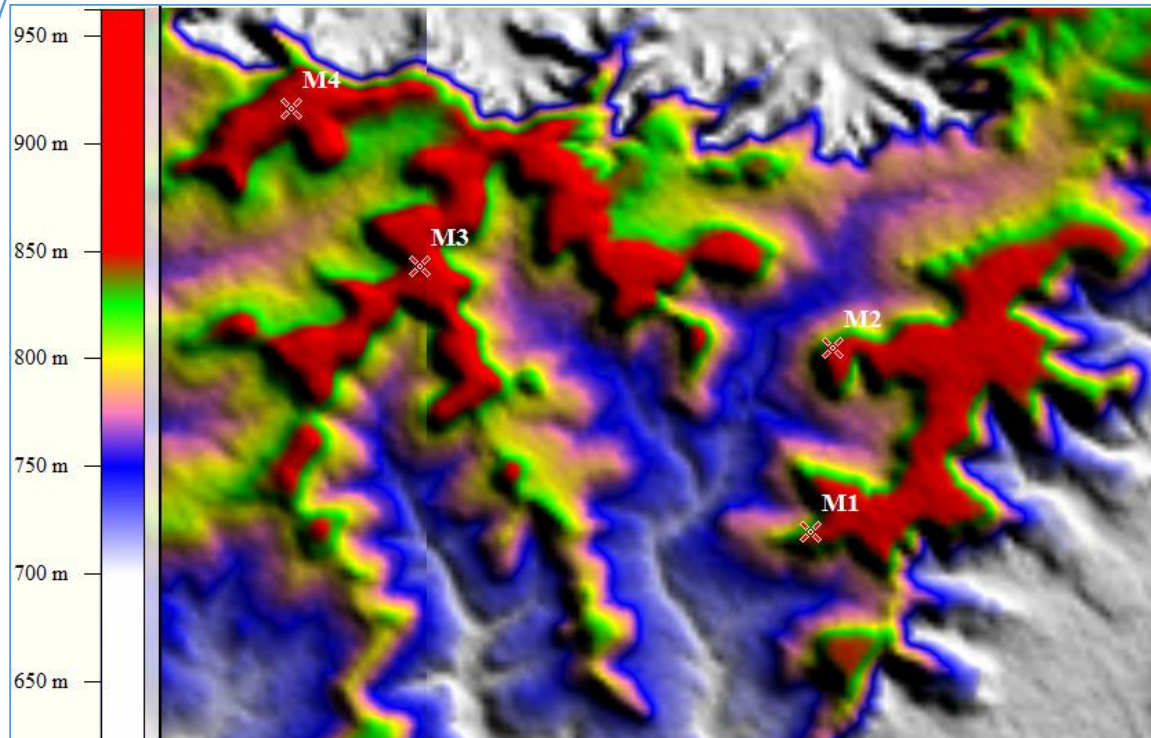
Conclusion

Site Details

- The Site is located in Central India, 25 km east of Ahmednagar, Maharashtra
- Planned site capacity is of 147 MW
- Suzlon 2.1 MW, 90m HH machines
- Very complex site with altitude gradients higher than 400 m with steep slopes exceeds 13 degrees
- Land cover is comprised of small shrubs, bushes and with no dense vegetation



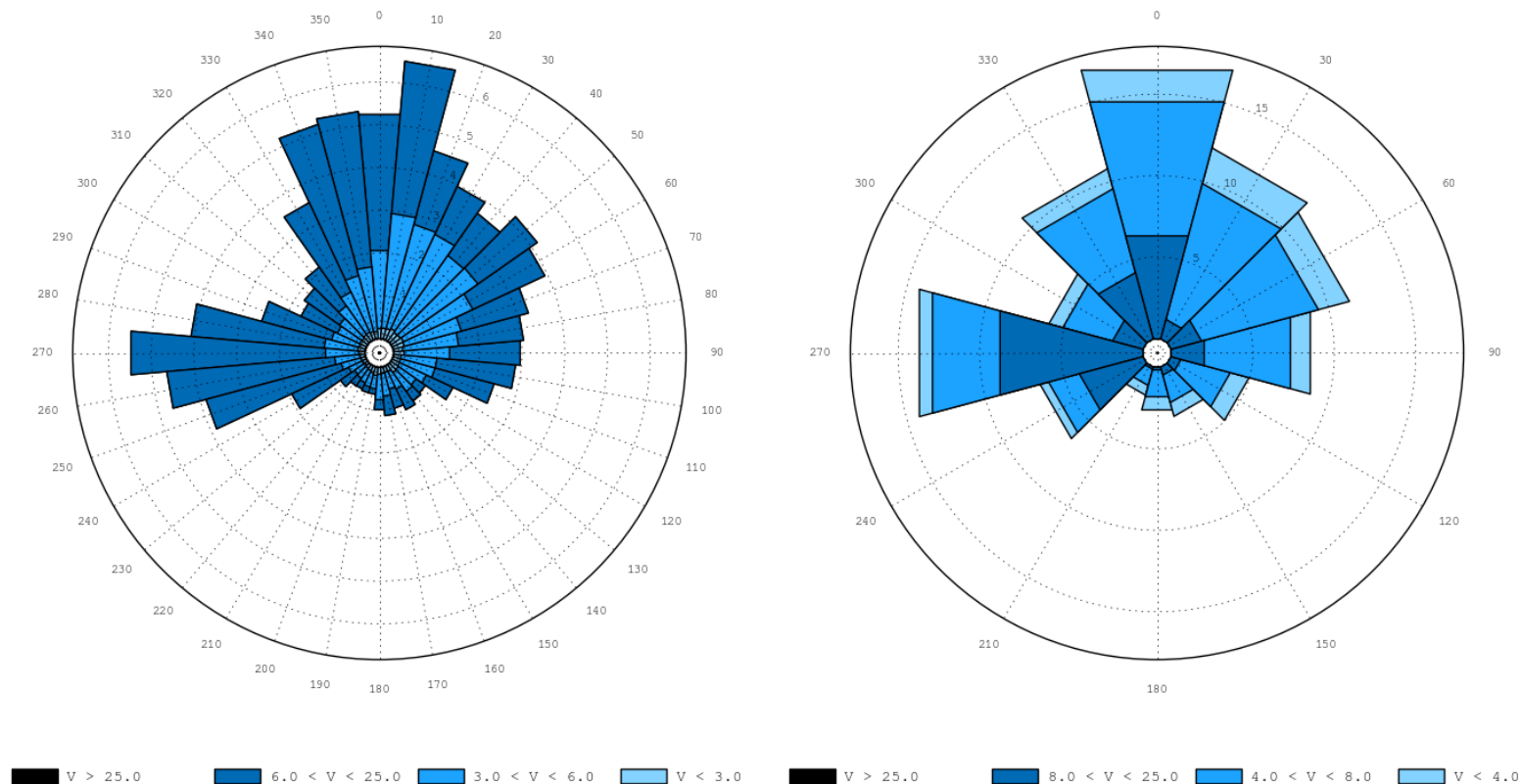
Elevation Profiles



Met Mast Details

Mast ID	Anem heights (m)	Wind vane heights (m)	Monitoring Period (Months)	Distance	M-01	M-02	M-03	M-04
M-01	78, 55, 40	76, 55	41	M-01	0.00	2.78	6.84	9.73
M-02	78, 55, 40	76, 55	41	M-02	2.78	0.00	6.00	8.49
M-03	95, 70, 50	90, 70, 50	12	M-03	6.84	6.00	0.00	2.98
M-04	95, 70, 50	90, 70, 50	12	M-04	9.73	8.49	2.98	0.00

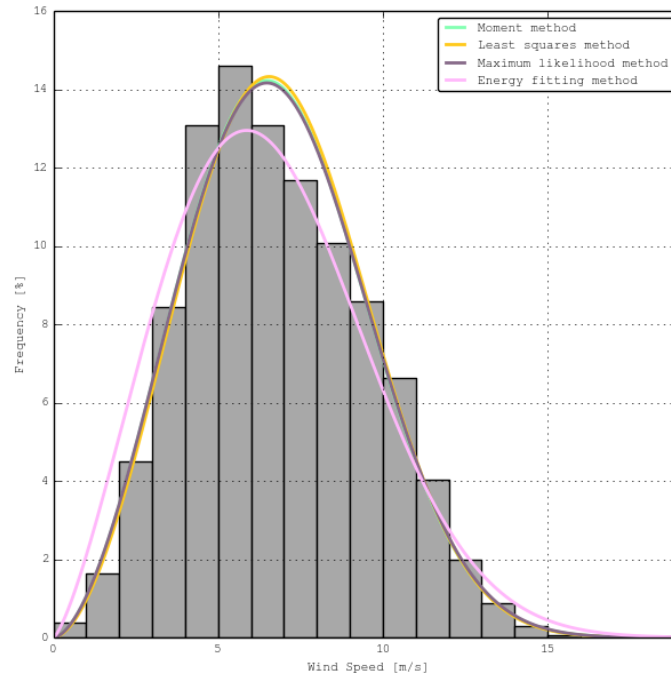
Measurements



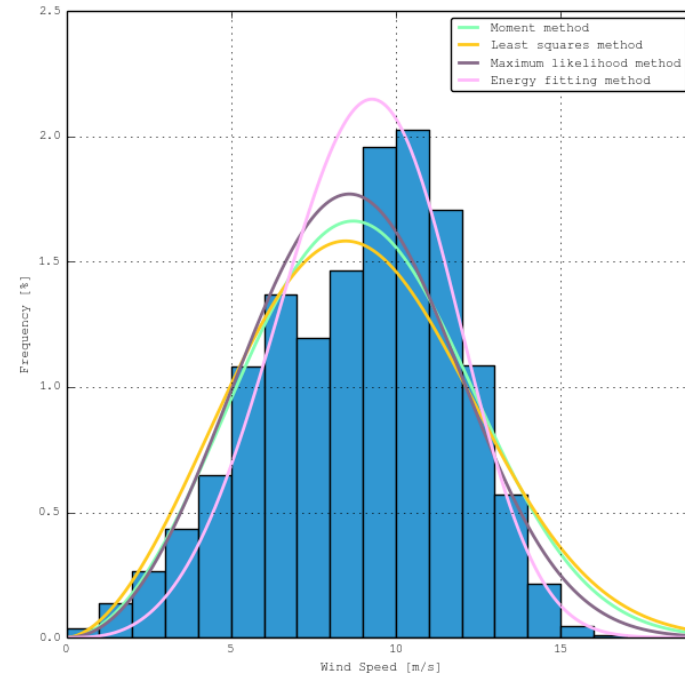
Wind Rose measured at M3 (h=95m)

Only the concurrent data (with M4 measurements) are plotted: 45989 synchronous data

Measurements



■ All directions



■ Sector: 270.0 deg

Wind Speed Histograms measured at M3 (h=95m)
Only the concurrent data (with M4 measurements) are plotted: 45989 synchronous data

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Project Status

Initial Work

- Start defining the complete project
- Generating some test meshes

Challenging CFD modeling

- The Random Access Memory directly drives the number of cells to be used
- The project being large and with strong hardware limitations, it was not possible to run calculations with horizontal resolutions higher than 120 meters

Resulting strategy

- Start with a reduced project focusing on M3 and M4 masts only
- Wait for ZephyTOOLS 0.8 to start with the calculations
 - OpenFOAM version 2.3.0 CFD engine
 - **Possibility to run ZephyTOOLS in the cloud**, in order to access to more appropriate computable mesh resolutions

Site & Measurements

Project Status

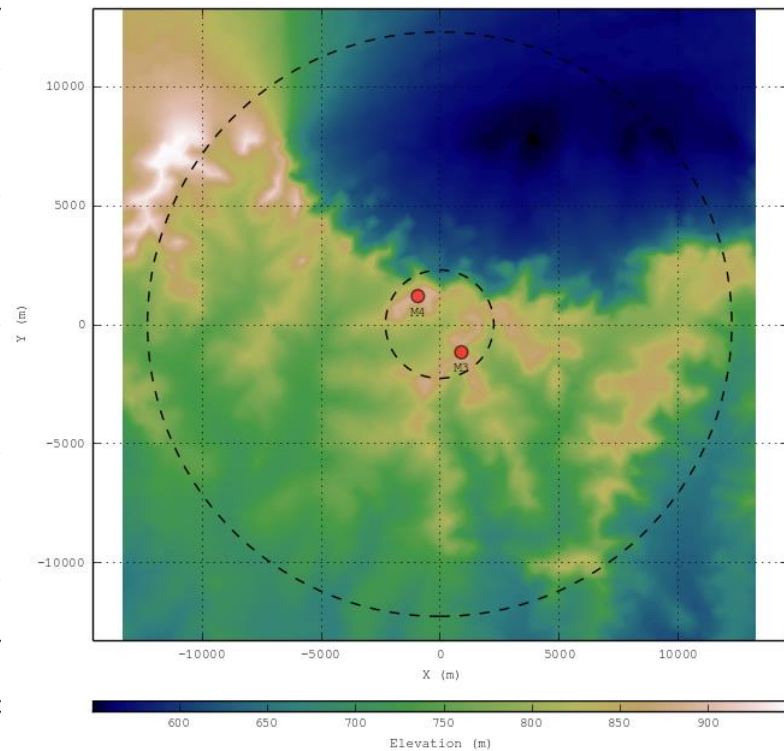
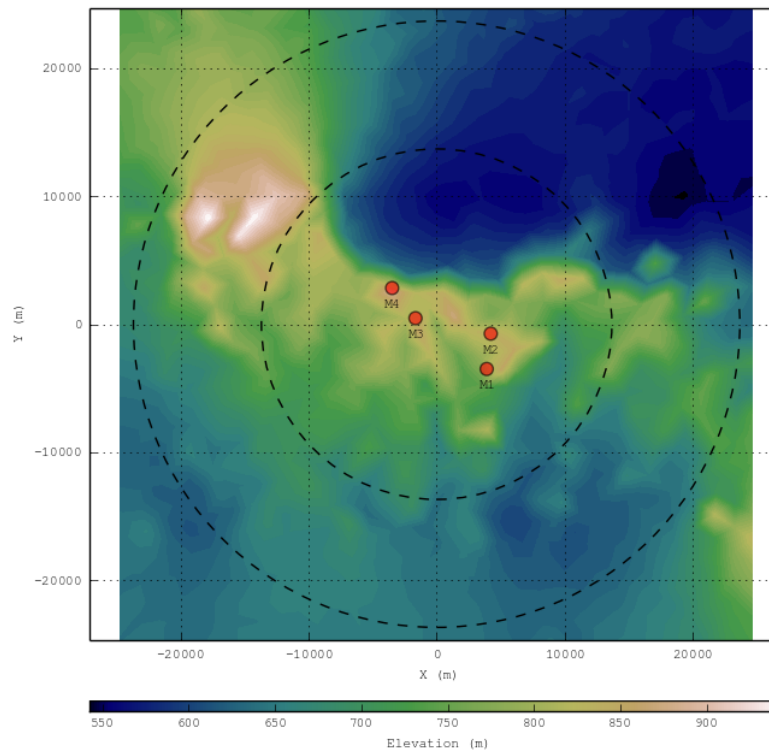
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Project Definition

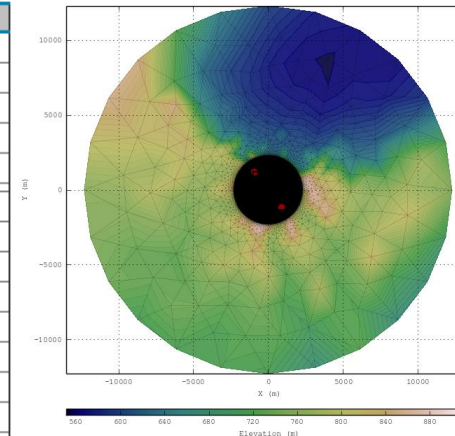
From initial configuration to reduced project size:



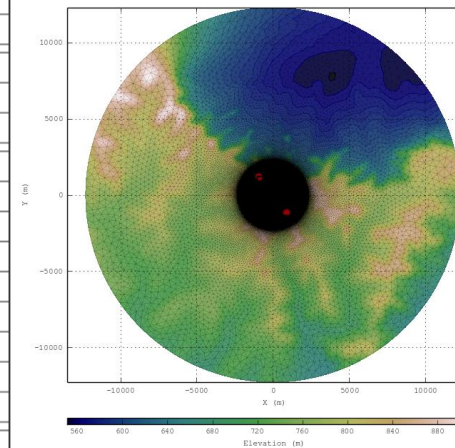
Mesh Generation

Comparison of the different sets of parameters (M1 mesher)

Information	Parameter	Unit	NDIR72	param
Refined Zone Diameter	diaref	m	4551.0	4551.0
Domain Diameter	diadom	m	4551.0	4551.0
Fine Zone Input Horizontal Mesh Resolution	resfine_init	m	20.0	20.0
Fine Zone Input Horizontal Mesh Resolution for Coarse Mesh	rescoarse_init	m	80.0	80.0
Number of Sectors	nsect	—	72	12
Domain Minimum Height	htop	m	2500.0	2500.0
Wind Turbine Zone Height	hturb	m	200.0	200.0
Canopy Zone Height	hcanop	m	10.0	10.0
Maximal Vertical Resolution	dztop	m	500.0	500.0
Wind Turbine Zone Maximal Vertical Resolution	dztop	m	8.0	8.0
Canopy Zone Maximal Vertical Resolution	dzcanop	m	4.0	4.0
Ground Minimal Vertical Resolution	dzmin	m	2.0	2.0
Top Zone Expansion Coefficient	exptop	—	1.2	1.2
Wind Turbine Zone Expansion Coefficient	expturb	—	1.1	1.1
Canopy Zone Expansion Coefficient	expcanop	—	1.1	1.1
Number of Smoothing	nsmo	—	1	1
Smoothing Coefficient	smoocoef	—	0.3	0.3
Inlet Smoothing	insmo	—	Without	Without
Number of Cells (fine)	ncells_fine	—	8170580	6228420
Number of Cells (coarse)	ncells_coarse	—	1218140	465850
Mesh Resolution in Refined Area	resfine	m	15.4	15.4
Mesh Resolution in Refined Area (coarse)	resfine_coarse	m	15.4	15.4
Mesh Resolution near Side Boundary Conditions	rescoarse	m	535.6	3213.7
Maximal Skewness	skewmax_fine	—	0.59	0.59
Maximal Skewness (coarse)	skewmax_coarse	—	0.48	0.48
Maximal Aspect Ratio	ratiomax_fine	—	166.21	607.77
Maximal Aspect Ratio (coarse)	ratiomax_coarse	—	142.52	696.11
Total Duration	duration_tot	h:m:s	01:19:33	01:00:25



nsect=12



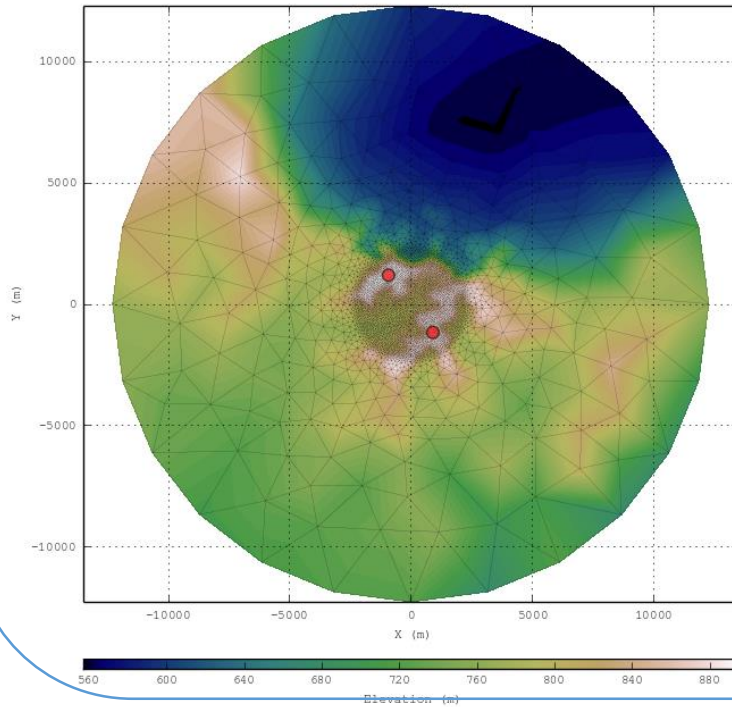
nsect=72

Allowing more computable directions for the prevailing winds

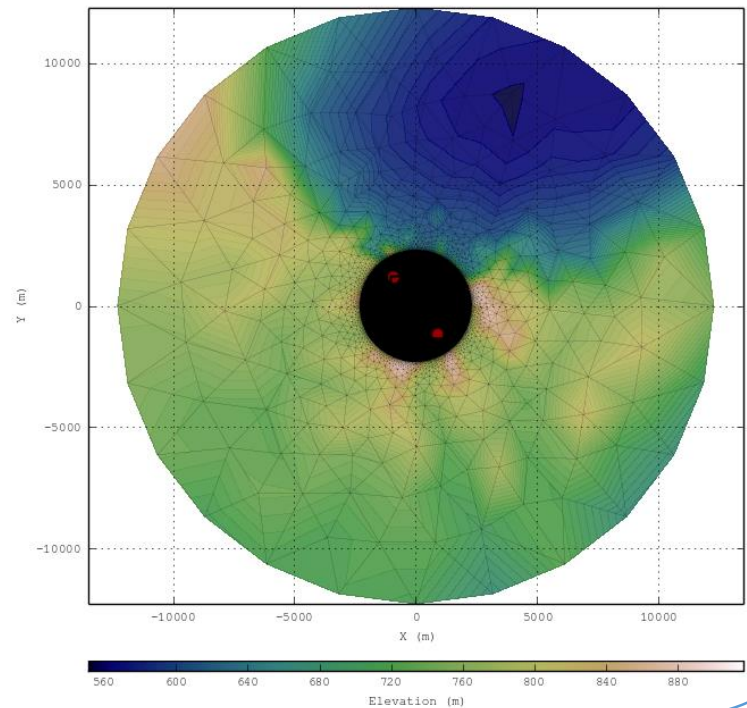
Mesh Generation

- Two meshes are automatically generated for optimized time / convergence (Coarse & Fine)
- Unique time-saving meshing process : Coarse & Fine cylindrical meshes built once for the whole rose!

Coarse Mesh

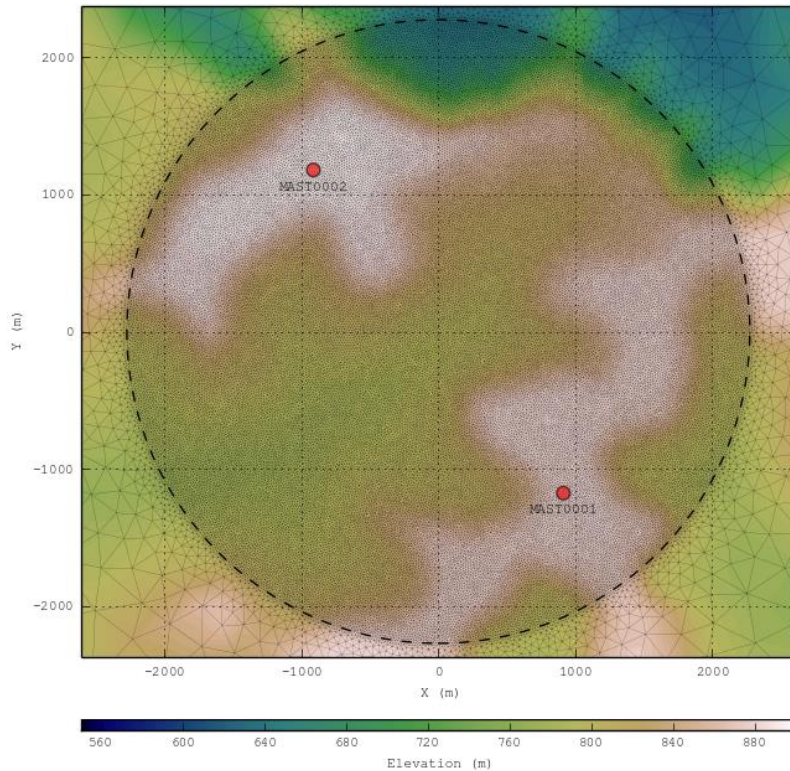


Fine Mesh

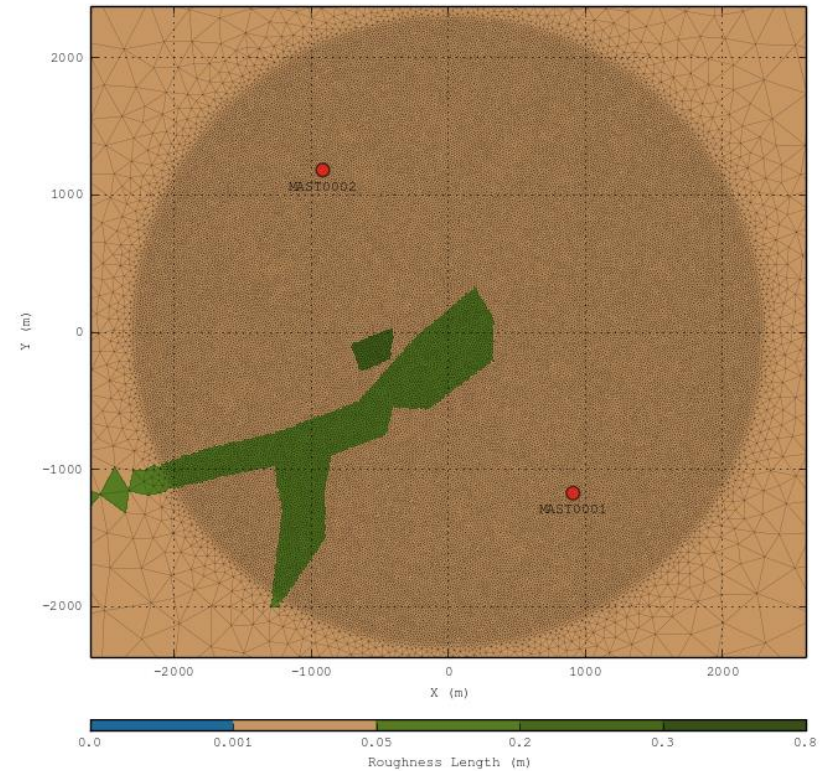


Mesh Visualization

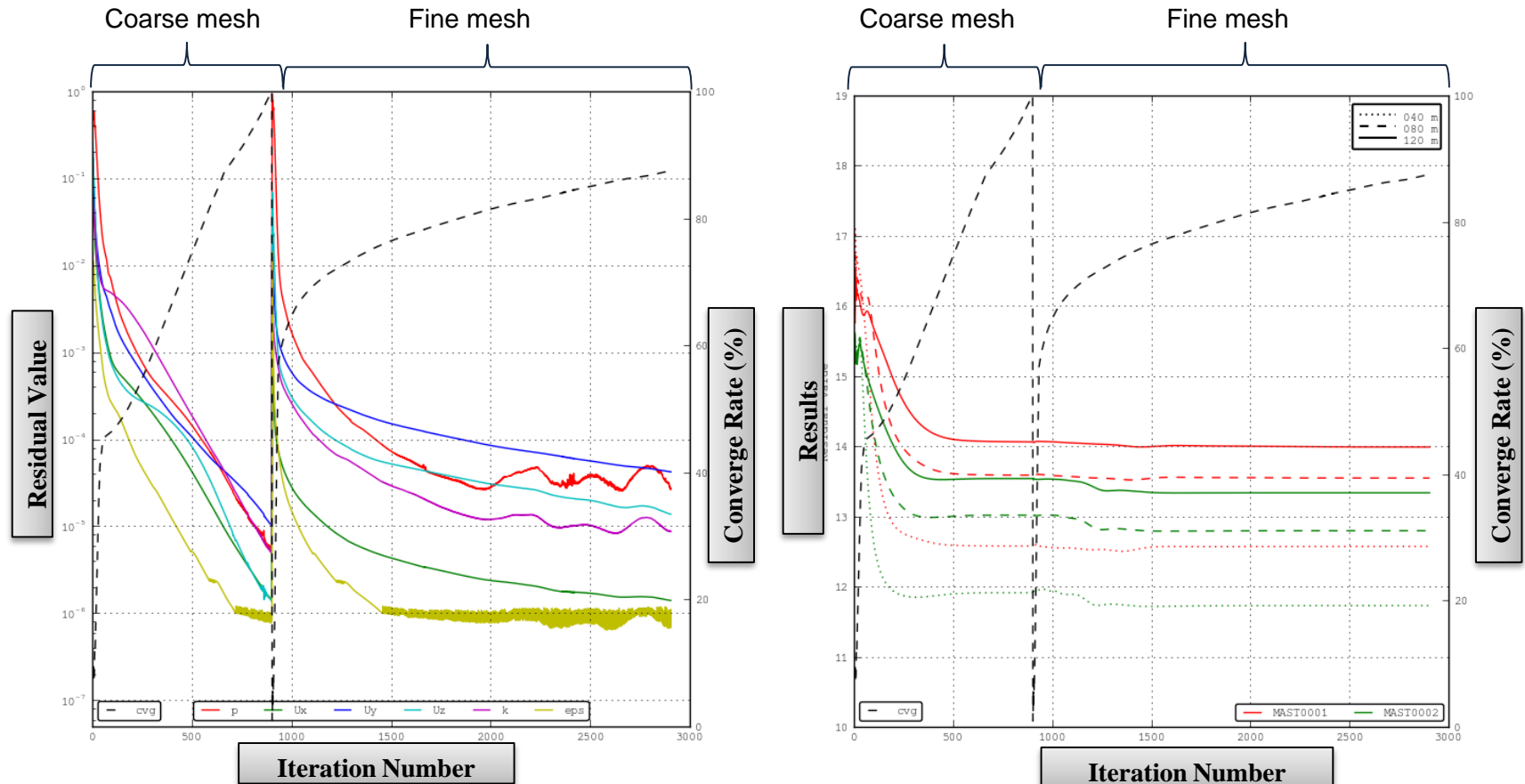
Altitude (Fine Mesh)



Roughness (Fine Mesh)



CFD Calculations – Convergence Control Window



- Mainly using the predefined parameters ("normal" set)
- Robust mode can be activated if convergence is challenging
- Convergence can be monitored in real-time : full transparency on model behavior

Site & Measurements

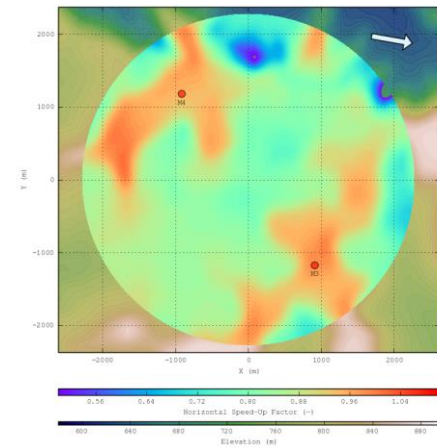
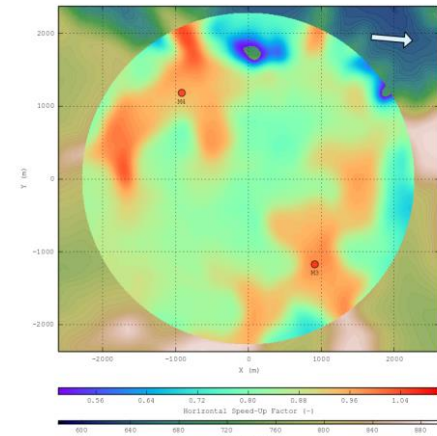
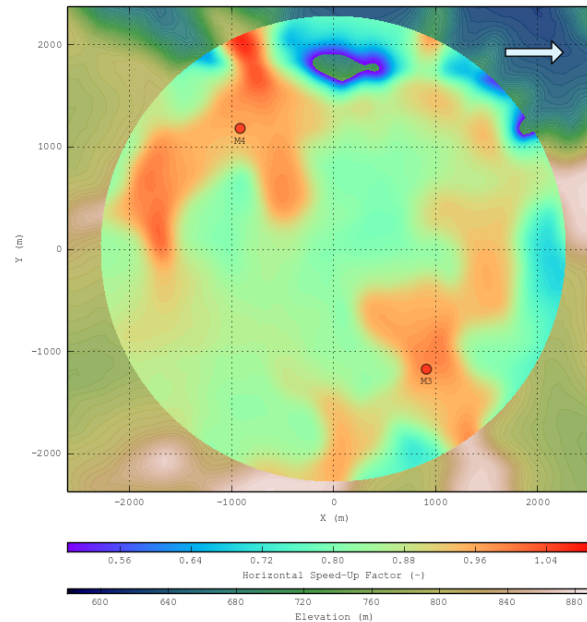
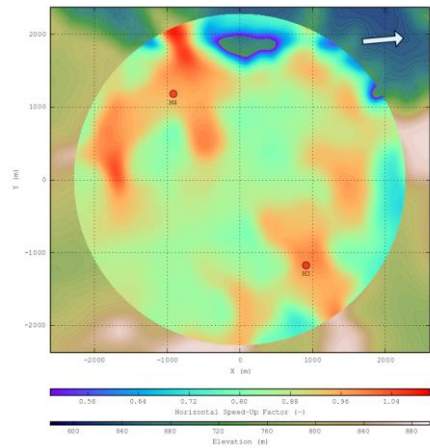
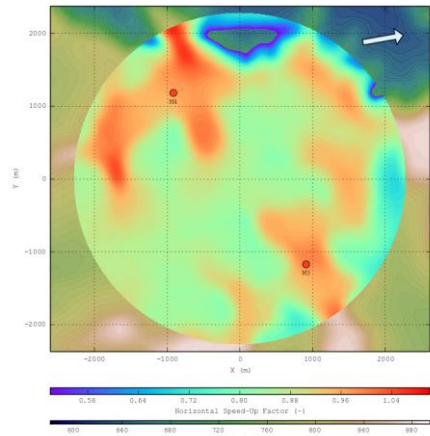
Review of Models

Modelling Parameters

Case Study Results

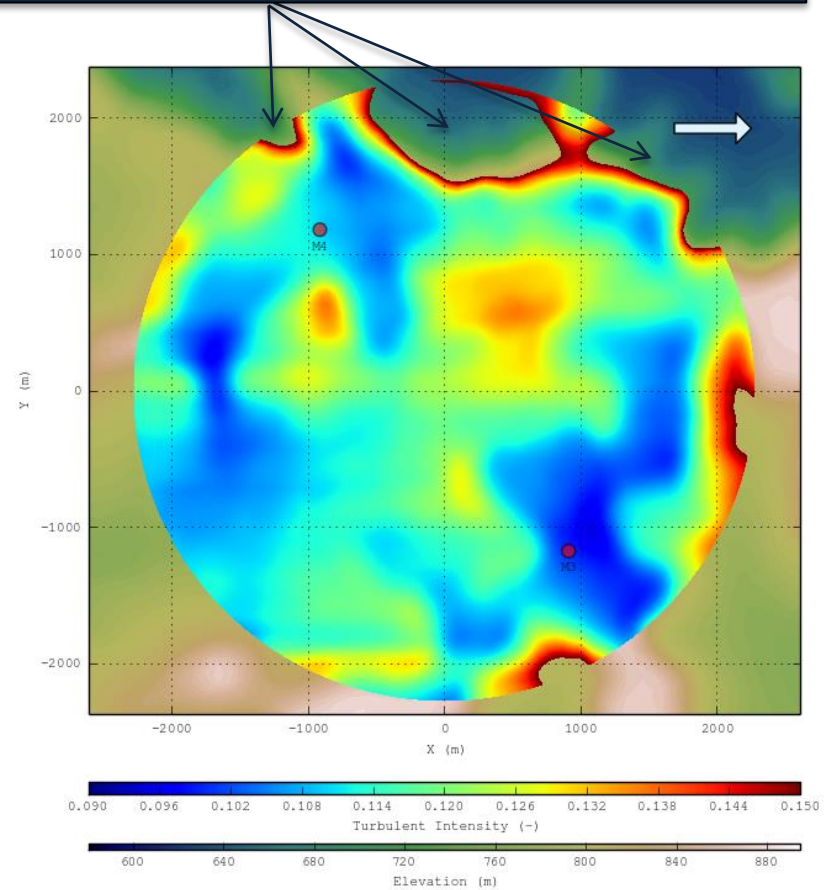
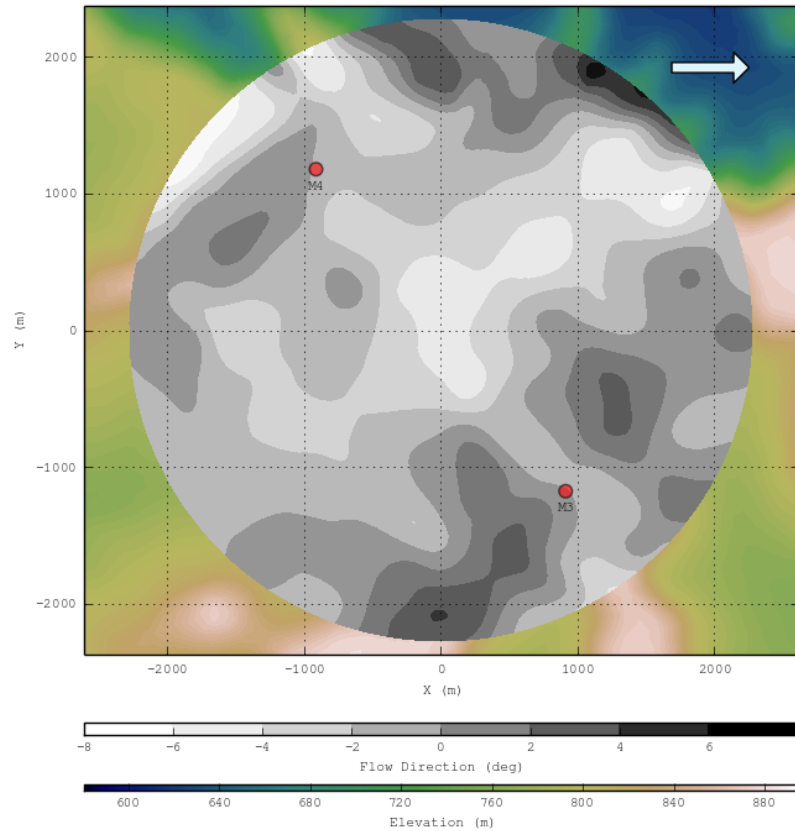
Conclusion

CFD Calculations – Results for prevailing winds



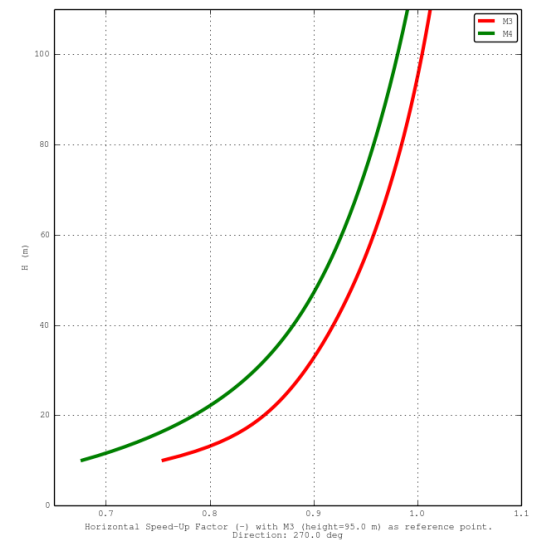
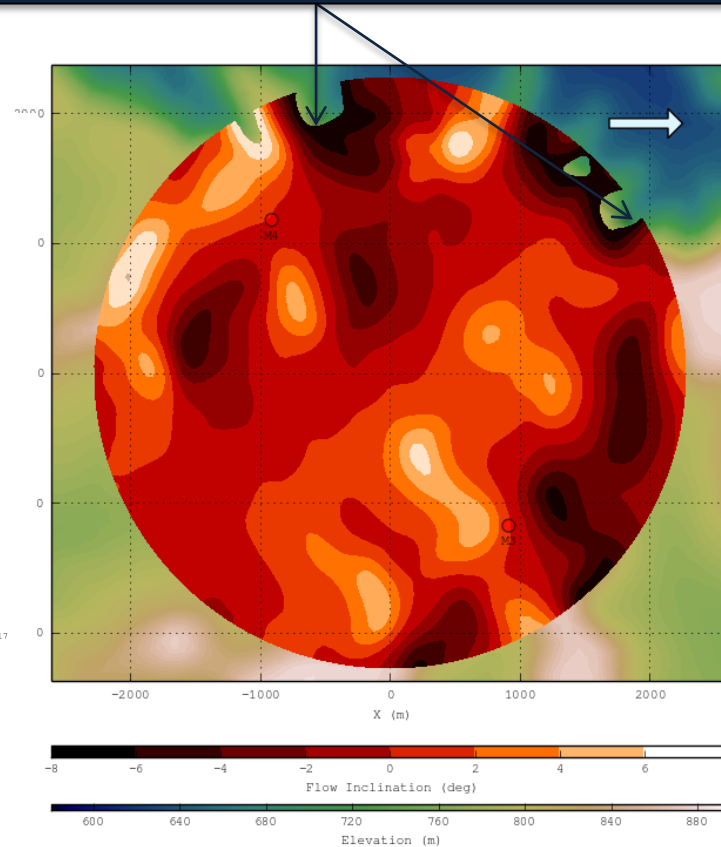
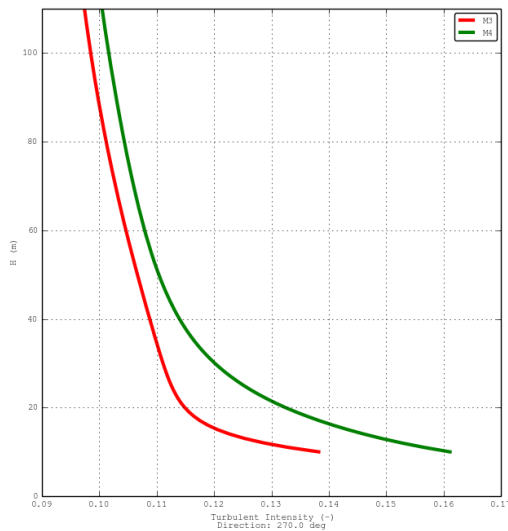
CFD Calculations – Results for prevailing winds

Mast Siting : High Turbulence zones can be automatically filtered out

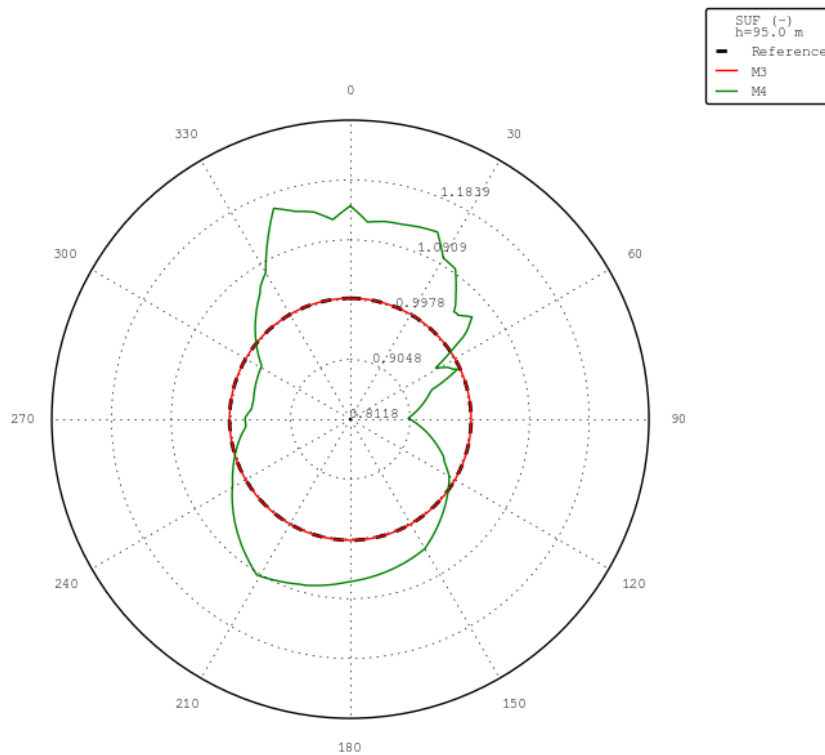


CFD Calculations – Results for prevailing winds

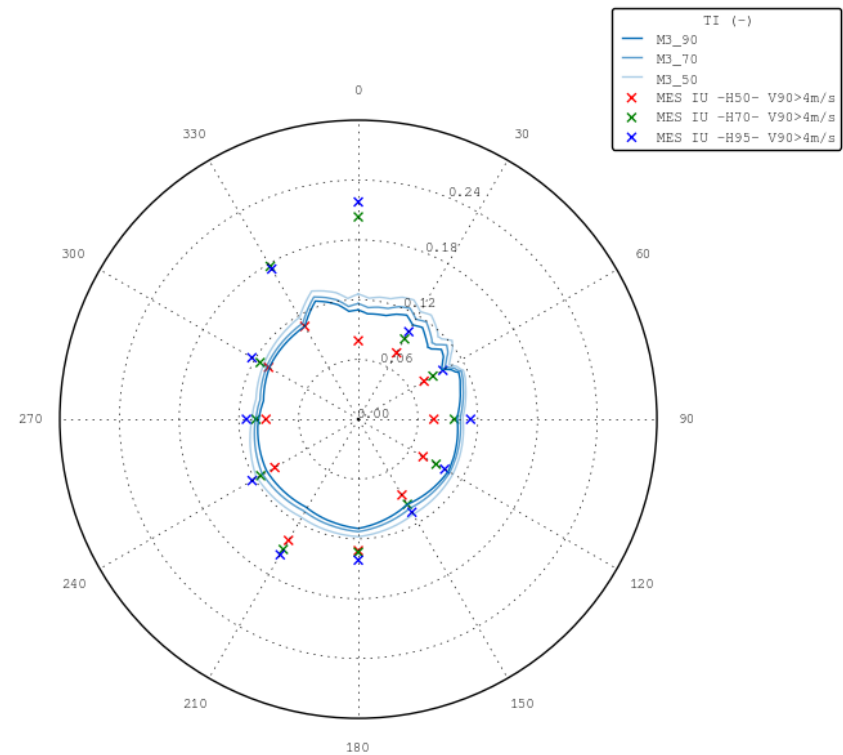
Mast Siting : High Inflow Angle zones can be automatically filtered out



Roses of Results : Full 360° understanding of wind flow characteristics

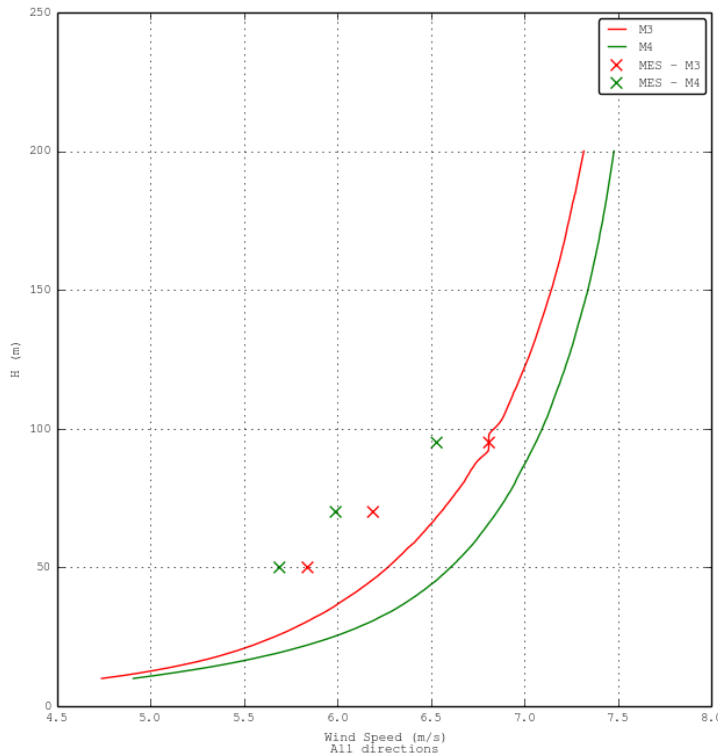


Speed-up Rose at M4 (Ref : M3)



Turbulence Rose at M3 (50m, 70m, 90m)

Extrapolation



- Important speed-up from M3 to M4 for the north directions (some prevailing ones)
- Measurements are showing different behavior, strongly affecting the extrapolated averaged wind speed
- Suspicious measurements from north directions (cf. turbulence rose)

Summarised Results

Model	Reference Mast	Target Mast	Measured Wind Speed (m/s)	Predicted wind speed (m/s)	Absolute Error	% Error
ZephyTOOLS	M3	M4	6.56	7.05	-0.52	8.0%
WAsP	M3	M4	6.56	7.1	-0.60	9.2%

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- The first results shows that both models are over predicting wind speeds at M4 location
- This over prediction is mainly due to high turbulence levels in the north direction induced by a high terrain complexity
- Even with a very coarse resolution, CFD is showing lower uncertainties in such complex scenario as compared to Wasp linear model

Going Forward....

- Masts M1 and M2 results of ZephyTOOLS to be included
- One more linear model to be included in this case study to validate both results (M1 to M2 & M3 to M4)

For updated results, please follow the link:

http://www.zephy-science.com/content/boulder_renew_html/index.html

Thanks!